XLVII.—*Notes on the Structure of the* Crinoidea, Cystidea, *and* Blastoidea. By E. Billings, F.G.S., Palæontologist of the Geological Survey of Canada*.

[Continued from p. 266.]

5. *On the Homologies of the Respiratory Organs of the Palæozoic and Recent Echinoderms, and on the "Convoluted Plate" of the* Crinoidea.

In a former note I have advanced the opinion that "The grooves on the ventral disk of *Cyathocrinus*, and also the internal '*convoluted plate*' of the palæozoic Crinoids, with the tubes radiating therefrom, belong to the respiratory and perhaps, in part, to the circulatory systems—not to the digestive system. The convoluted plate, with its thickened border, seems to foreshadow the 'œsophageal circular canal,' with a pendent madreporic apparatus as in the Holothuridea" (*ante*, p. 255, note.) I should have referred it to the madreporic system of the existing Echinodermata in general, instead of to that of the Holothuridea in particular. At the time the note was written I had in view the madreporic sac of *Holothuria*, which, as will be shown further on, most resembles in form that of *Actinocrinus*. The figures and descriptions which follow are intended to show the gradual passage or conversion of the respiratory organs of the Cystidea, Blastoidea, and Palæocrinoidea into the ambulacral canal-system of the recent Echinoderms, and that, as the convoluted plates of the former have the same structure and connexions as the madreporic sacs and tubes or sand-canals of the latter, they are most probably all the homologues of each other.

Among the Cystideans we find several genera, such as *Cryptocrinites*, *Malocystites*, *Trochocystites*, and apparently some others, whose test is totally destitute of respiratory pores, being composed of simple solid plates like those of the ordinary Crinoidea. In a second group of genera, among which may be enumerated *Caryocystites*, *Echinosphærites*, *Palæocystites*, and *Protocystites*, the whole of the external integument seems to have been respiratory, as all or nearly all of the plates of which it is composed are more or less occupied by variously arranged poriferous or tubular structures. The Cystideans of these two groups hold the lowest rank of all those known. In their general structure they are mere sacs, of a globular, ovate, or (as in the case of *Trochocystites*) flattened form. Their test consists of an indefinite number of plates without any radiated arrangement. They were also, according to our present knowledge, the first to make their appearance, two of

* From Silliman's American Journal of Science, January 1870.

Fig. 1.

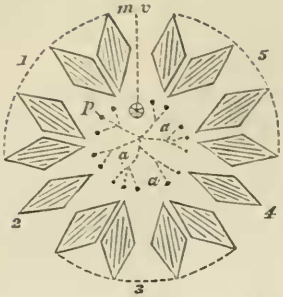

Fig. 2.

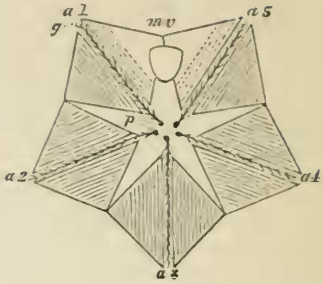

Fig. 3.

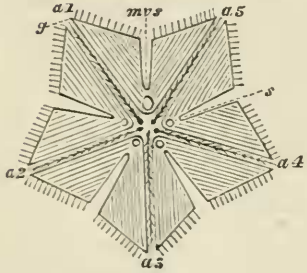

Fig. 4.

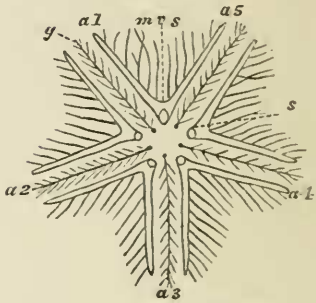

Fig. 5.

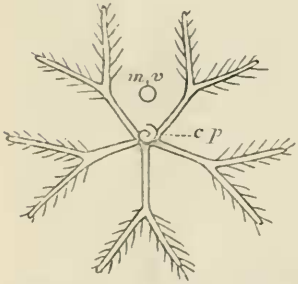

Fig. 6.

Fig. 7.

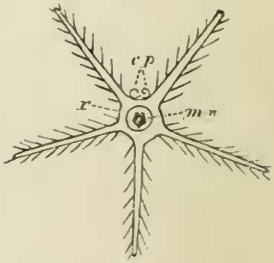

Fig. 1. The upper part of *Caryocrinus ornatus*, the test being removed in order to show the internal structure of the fourteen hydrospires that surround the summit. The parallel lines represent the flat tubes. The other figures exhibit the modifications which the hydrospires undergo in passing through :—fig. 2. *Codaster*; fig. 3. *Pentremites* with broad ambulacra; fig. 4. *Pentremites* with single tubes; fig. 5. Palæozoic Crinoids with a convoluted plate attached to the centre of radiation; fig. 6. Sand-canal or madreporic tube of a starfish, enclosing a doubly convoluted plate; fig. 7. Ambulacral canals of a starfish with the doubly convoluted plate of the sand-canal attached to the œsophageal ring. The following letters have the same reference in all the figures

the genera, *Trochocystites* and *Eocystites*, having been discovered in the primordial zone. No other Echinoderms have been found in rocks of so ancient a date.

Next in order may be placed those genera whose test is composed of a definite number of plates, which have, to some extent, a quinary arrangement. Thus *Glyptocystites*, *Echinoencrinites*, *Apiocystites*, and several others have each four series of calycine plates, of which there are four plates in the basal and five in each of the other three series. The respiratory areas or hydrospires are reduced in number—ten to thirteen in *Glyptocystites*, and three in most of the other genera of the group. Neither in the plates nor in the hydrospires is there exhibited any tendency to a radiated arrangement. The most ancient genus of this family is *Glyptocystites*, which first appears in the Chazy Limestone, and seems to have become extinct in the Trenton. The other genera occur in various horizons between the Chazy and the Devonian.

In the genera *Hemicosmites* and *Caryocrinus* the hydrospires in the upper part of the test converge toward but do not reach the central point of the apex, thus forming the commencement of that concentration and complete radiation which is exhibited in the ambulacral canal-system of the higher Echinoderms. In a former note (*ante*, p. 259) it is pointed out that *Caryocrinus* has thirty hydrospires—ten at the base with their longer diagonals vertical, a zone of six round the middle with their diagonals horizontal, and a third band of fourteen around the upper part of the fossil. These latter are represented in fig. 1 as if spread out on a plane surface. On consulting this figure, it will be seen that the flat tubes of the hydrospires, represented by the parallel lines, all converge toward the central point from which the dotted lines radiate. This point is the position of the mouth in the recent Echinoderms; but in *Caryocrinus* it is occupied by a large solid imperforate plate. The hydrospires are arranged in five groups. Commencing at *m v* and going round by 1, 2, &c., there are four in the first group, one in the second, four in the third, one in the fourth, and four in the fifth. These five groups represent the five ambulacral canals of the recent Echinoderms. In the specimen from which this diagram was constructed there are the bases of fifteen free arms to be seen, situated at the outer extremities of the dotted lines. At the base of each arm there is a small pore (*p*), which I believe to

in which they occur:—*a*, an arm or ambulacrum; *m v*, mouth and vent combined in a single aperture; *m v s*, mouth, vent, and spiracle; *g*, ambulacral groove; *p*, ovarian pore; *s*, spiracle: *cp*, convoluted plate; *r*, œsophageal ring.

have been exclusively ovarian in its function. The hydrospires have no connexion whatever with the arms, and are, moreover, all of them entirely separated from each other. If, then, they represent the ambulacral system of the recent Echinoderms, it is quite certain that that system was at first (or in the undeveloped stage in which it existed in the Cystidea) destitute of the œsophageal ring.

In *Codaster* a further concentration of the respiratory organs is exhibited. There are here only five hydrospires, and they are all confined to the circle around the apex. Two of them are incomplete, in order to make room for the large mouth and vent (*m v*, fig. 2). They are each divided into two halves by an arm *a*1 *a*2, &c. They are only connected with the arms to this extent, that these latter lie back upon them. The arms are provided with pinnulæ; but it is not at all certain that the pinnulæ were in any direct communication with the hydrospires. It is evident that *in all the Cystidea* (and in none is it more obvious than in *Caryocrinus*) there was no connexion between the hydrospires and the pinnulæ. The main difference (so far as regards the evidence of the presence or absence of such a connexion) between *Caryocrinus* and *Codaster* consists in this, that in the former the arms are erect and do not touch the hydrospires, whereas in the latter they are recumbent and lie back upon them. Each of the arms of *Codaster* has a fine ambulacral groove; and all of the grooves terminate in a single central aperture. But, as this aperture was covered over by a thin plated integument, as in the Blastoidea, I have not shown it in the diagram, but only the five pores, *p*.

No one who compares a *Codaster* with a *Pentremites* (the internal structure of the latter being visible) can doubt that the hydrospires of the two genera are perfectly homologous organs. If we grind off the test of a species of the latter genus, selecting one for the purpose which has broad petaloid ambulacra, such as those of *P. Schultzii*, the structure exposed will be that represented in the diagram fig. 3. In *Pentremites*, as in *Codaster*, the five hydrospires are divided into ten equal parts by the five rays, *a*1, *a*2, &c. In *Codaster* these ten parts remain entirely separate from each other; but in *Pentremites* they are reunited in pairs, the two in each interradial space being so connected at their inner angles that their internal cavities open out to the exterior through a single orifice or spiracle (*s*, figs. 3 & 4). This is best shown in fig. 4, intended to represent the structure of *P. ellipticus* (Sowerby), as described by Mr. Rofe, Geol. Mag. vol. ii. p. 249. In this species the hydrospires, instead of being formed of broad sacs

with a number of folds on one side, consist of ten simple cylindrical tubes connected together in five pairs. The only difference between the structure of fig. 3 and fig. 4 is in the width of the tubes and in the absence of folds in the latter. These two forms are, moreover, connected by intermediate grades. Species with eleven, ten, eight, six, five, four, and two folds being known, there is thus established a gradual transition from the broad petaloid form to the single cylindrical tube.

Between the Cystidea and the Blastoidea the most important changes are that in the latter the hydrospires become connected in pairs, and also are brought into direct communication with the pinnulæ. In the palæozoic Crinoidea (or at least in many of them) concentration is carried one step further forward, the five pairs of hydrospires being here all connected together at the centre, as in fig. 5. There is as yet no œsophageal ring (as I understand it), but in its place the convoluted plate described in the excellent papers of Messrs. Meek and Worthen. This organ, according to the authors, consists of a convoluted plate resembling in form the shell of a *Bulla* or *Scaphander*. It is situated within the body of the Crinoid, with its longer axis vertical and the upper end just under the centre of the ventral disk. Its lower extremity approaches, but does not quite touch, the bottom of the visceral cavity. Its walls are composed of minute polygonal plates, or of an extremely delicate network of anastomosing fibres. The five ambulacral canals are attached to the upper extremity, radiate outward to the walls of the cup, and are seen to pass through the ambulacral orifices outward into the grooves of the arms. (Silliman's Journ. vol. xlviii. p. 31.)

The ambulacral canals of the Crinoidea are, for the greater part, respiratory in their function. They are, however, as most naturalists who have studied their structure will admit, truly the homologues of those of the Echinodermata in general. In the higher orders of this class the canals are usually more specialized than they are in the lower, being provided with prehensive or locomotive organs. In all of the existing orders, including the recent Crinoidea, we find an œsophageal ring.

To this organ, which is only a continuation of the canals, are attached the madreporic appendages. These consist of small sacs or slender tubes, varying greatly in form and number in the different genera. That of the starfish *Asteracanthion rubens* is thus described by Prof. E. Forbes:—"On the dorsal surface is seen a wart-like striated body placed laterally between two of the rays: this is the *madreporiform tubercle or*

nucleus. When the animal is cut open, there is seen a curved calcareous column running obliquely from the tubercle to the plates surrounding the mouth; Dr. Sharpey says it opens by a narrow orifice into the circular vessel. It is connected by a membrane with one side of the animal, and is itself invested with a pretty strong skin, which is covered with vibratile cilia. Its form is that of a plate rolled in at the margins till they meet. It feels gritty, as if full of sand. When we examine it with the microscope, we find it to consist of minute calcareous plates, which are united into plates or joints, so that when the investing membrane is removed, it has the appearance of a jointed column. Professor Ehrenberg remarked the former structure, Dr. Sharpey the latter: they are both right. Both structures may be seen in the column of the common cross-fish." (Forbes, 'British Starfishes,' p. 73.)

In Prof. Joh. Müller's work, 'Ueber den Bau der Echinodermen,' several forms of the madreporic appendages of the different groups of the recent Echinodermata are described. In general they are composed of a soft or moderately hard skin consisting of a minute tissue of calcareous fibres or of small polygonal plates. The walls are also sometimes minutely poriferous. In all the Holothurians the madreporic organ is a sac attached by one of its ends to the œsophageal canal, the other extremity hanging freely down into the perivisceral cavity, not connected with the opposite body-wall, as is the sand-canal of the starfishes (*op. cit.* p. 84). In its consisting of a convoluted plate, the madreporic organ of *Actinocrinus* therefore agrees with that of the starfishes, while in its being only attached at one extremity it resembles that of the Holothurians.

The convoluted plate of the palæozoic Crinoids and the madreporic sacs and tubes (or sand-canals) of the recent Echinoderms, therefore, all agree in the following respects:—

1. They have the same general structure.
2. They are all appendages of the ambulacral system.
3. They are all attached to the same part of the system—that is to say, to the central point from which the canals radiate.

The above seems to me sufficient to make out at least a good *primâ facie* case for the position I have assumed. When among the petrified remains of an extinct animal we find an organ which has the same general form and structure as has one that occurs in an existing species of the same zoological group, we may, with much probability of being correct in our opinion, conclude that the two are homologous, even although we may not be able positively to see how that of the fossil is

connected with any other part. But when, as in this instance, we can actually see that it is an appendage of another organ (or system of organs, rather), which is known to be the homologue of the part with which that of the existing species is always correlated, we have evidence of a very high order on which to ground a conclusion. By no other mode of reasoning can we prove that the column of an *Actinocrinus* is the homologue of that of *Pentacrinus caput Medusæ*.

In an important paper entitled "Remarks on the Blastoidea, with Descriptions of New Species," which Messrs. Meek and Worthen have kindly sent me, the authors, in their comments upon my views, state that—

"In regard to the internal convoluted organ seen in so many of the Actinocrinidæ, belonging to the respiratory instead of the digestive system, we would remark that its large size seems to us a strong objection to such a conclusion. In many instances it so nearly fills the whole internal cavity that there would appear to be entirely inadequate space left for an organ like a digestive sac outside of it, while the volutions within would preclude the presence of an independent digestive sac there. In addition to this, the entire absence, so far as we can ascertain, of any analogous internal respiratory organ in the whole range of the recent Echinodermata, including the existing Crinoids, would appear to be against the conclusion that this is such, unless we adopt the conclusion of Dujardin and Hupé, that the palæozoic Crinoids had no internal digestive organs, and were nourished by absorption over the whole surface. We should certainly think it far more probable that this spiral organ is the digestive sac than a part of a respiratory apparatus."

The objection here advanced does not appear to me to be a strong one. In many of the lower animals the digestive organs are of inconsiderable size in proportion to the whole bulk. In the Brachiopoda, for instance, the spiral ciliated arms fill nearly the whole of the internal cavity, the digestive sac being very small and occupying only a limited space near the hinge. These arms, although not the homologues of the convoluted plates of the palæozoic Crinoids, have a strong resemblance to them, and are, moreover, at least to some extent, subservient to respiration. They are certainly not digestive sacs. In the recent Echinoderms the intestine is usually a slender tube with one or more curves between the mouth and the anus. It fills onlya small part of the cavity of the body, the remainder being occupied mostly by the chylaqueous fluid, which is constantly in motion and undergoing aëration through the agency of various organs, such as the respiratory tree and branchial

cirri of the Holothuridæ, the dorsal tubuli of the Asteridæ, and the ambulacral systems of canals of the class generally. In no division of the animal kingdom do the respiratory organs occupy a larger proportion of the whole bulk than they do in the Echinodermata. The great size which the convoluted plate attains in some of the Crinoids is therefore rather more in favour of its being a respiratory than a digestive organ.

Professor Wyville Thomson says that, inside of the cavity of the stomach of the recent Crinoid *Antedon rosaceus*, there is a spiral series of glandular folds, which he supposes to be a rudimentary liver (Phil. Trans. R. S. 1865, p. 525). It is barely possible that the convoluted plate may represent this organ. At present I think it does not.

I believe that the reason why the convoluted plate attained a greater proportional size in the palæozoic Crinoids than do the sand-canals of the recent Echinoderms, is that the function of the system of canals (of which they are all appendages) was at first mostly respiratory, whereas in the greater number of the existing groups it is more or less prehensive or locomotive, or both.

[To be continued.]

XLVIII.—*Descriptions of some new Species of Birds from Southern Asia.* By Arthur, Viscount Walden, P.Z.S. &c.

Geocichla layardi, n. sp.

The *Geocichla* of Ceylon is most nearly allied to *G. citrina*, (Lath.), of Northern and Central India, and not, as might have been expected, to *G. cyanota*, (J. & S.), of Malabar. From Latham's bird it is to be readily distinguished by the much deeper orange of the head and nape, these parts being of the same dark shade of orange-brown characteristic of *G. rubecula*, Gould, ex Java. On the under surface the orange tints are brighter and richer than in *citrina*, yet not nearly so dark as in *G. rubecula*; the blue-grey portion of the plumage is likewise darker than in *G. citrina*, but not so dark as in *G. rubecula*. In the distribution of the white plumage the three species resemble each other; they appear, along with *G. rubiginosa*, Müller, ex Timor, to form a small natural section. Wing $4\frac{3}{8}$ inches, bill $\frac{4}{5}$.

Described from a single Ceylon example, and which is marked by the collector as "rare."